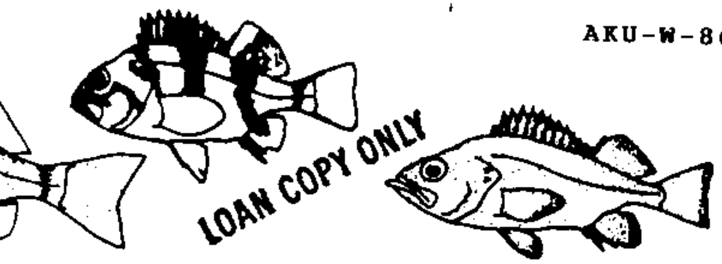

Lowell Wakefield
Fisheries Symposium

Proceedings of the International Rockfish Symposium

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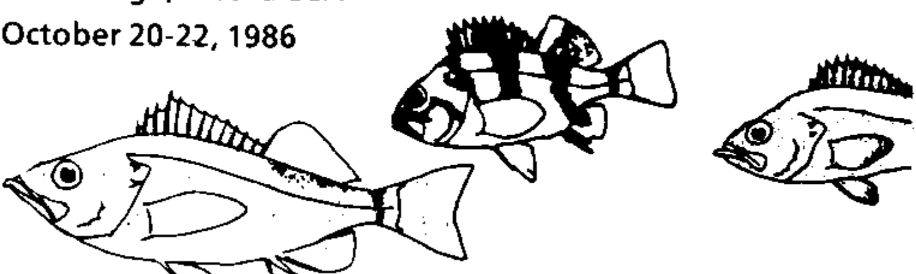

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Status of early life history studies of northeast Pacific rockfishes

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Abstract

Rockfishes (*Sebastes* spp.) are highly unusual in that they have internal fertilization of a large number of eggs ($>10^5$) and give birth to planktonic larvae at the first feeding stage. Following the planktonic larval stage, juveniles develop in a variety of habitats, depending on the species. Some remain pelagic for several months, while others become demersal at a small size. Since about 70 species of rockfish occur in the northeast Pacific, identifying the larvae and juveniles is a major problem. Recent studies have greatly enhanced our ability to identify these young stages, which allows us to contemplate using them to address fishery-related problems. Current studies are focused on relating the abundance of larvae and juveniles of rockfish to the adult populations, to measure both adult biomass and recruitment. These studies show promise, but the unusual biology of the genus limits somewhat the potential of such studies for fishery management purposes.

Early Life History Pattern

Rockfishes have an unusual reproductive pattern with important implications for their ecology and fisheries on their populations. Most fish that reproduce in marine waters lay free-floating planktonic eggs that are fertilized and undergo embryonic development as independent organisms in the open sea. Hatching is followed by a yolk-sac period about one-half as long as incubation, during which the larva develops eye pigment and feeding mechanisms. In rockfishes, however, fertilization occurs internally and the eggs develop and hatch inside the ovary of the female. It has recently been found that the embryos ingest ovarian fluid as a supplement to the yolk (see Boehlert, Kusakari, and Yamada, this volume). When the larvae are extruded after several weeks, they have little yolk left and are ready to begin feeding. These larvae are about 3-7 mm standard length (SL), comparable in size to first-feeding larvae of species with planktonic eggs.

Mortality of planktonic fish eggs, due primarily to predation, is high for the few species that have been studied in enough detail to make reliable estimates. Generally more than 50% of the pelagic eggs spawned by a fish die before hatching (Hempel 1979). Mortality of yolk-sac larvae in the field is even more difficult to examine but predators that feed on eggs probably also consume yolk-sac larvae. Thus, less than 20% of eggs spawned may survive through the yolk-sac period to become free-feeding larvae. Boehlert et al. (this volume) estimate that there is about 25% mortality of young in rockfishes between fertilization and parturition. Thus, the number of surviving first-feeding larvae in rockfishes is about 75% of the number of eggs that undergo ovulation, rather the 20% or less of that number in fishes spawning pelagic eggs. Also, the reproductive pattern of rockfishes reduces the amount of dispersion of planktonic stages by ocean currents.

Fecundity of rockfishes is high (10^4-10^6 eggs per female) and is only slightly lower than it is in fishes spawning pelagic eggs. In fish with more extensive protection of the young, or those that produce considerably larger eggs, fecundity is reduced substantially. It would seem that rockfishes have not achieved the concomitant reduction in fecundity generally associated with increased parental contribution to the welfare of individual progeny. The evolutionary advantage of gestation in rockfishes is unclear, but apparently it is not completely explained by protection of the egg and early larval stages. Internal fertilization may allow distinct but similar species to co-occur with little chance of cross-fertilizing their gametes. Behavioral or other prezygotic barriers would prevent copulation among closely related species. This reproductive strategy may have contributed to the genus becoming so speciose in the North Pacific.

Seasonality of Reproduction

Reproductive events in rockfishes follow this sequence: spermatogenesis, vitellogenesis, mating, ovulation, fertilization, embryonic development, hatching, and larval extrusion. Males mature up to several months before the females, and mating may precede fertilization by several months. Embryonic development takes about 40-50 days, and the larvae hatch about 1 week prior to extrusion. Although most rockfishes release larvae during the first 6 months of the year, there is quite a bit of variation among the species, and within a species among years.

When comparing information on seasonality of reproduction, the methods and criteria used and the sample sizes must be evaluated. Most work to date has been done off British Columbia and north/central California. Wyllie Echeverria (in press) has summarized information on reproductive seasonality of 34 species of northeast Pacific rockfish. The duration of larval release varies from 1 to 9 months among the species studied, and a few species demonstrated two periods of release during the year (Table 1). In general, species can be grouped into those that extrude larvae in winter and those that extrude larvae in spring-summer.

Table 1.--Periods of release of rockfish larvae. Based on Wyllie Echeverria (in press).

Gulf of Alaska —— B.C .... WA --- OR —— N. C. CA —·— S. CA -·-·

Species	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	References
S. aleutianus													1,2
S. alutus													1,2,3,4,21
S. auriculatus													5,6,7,21
S. aurora													1,2
S. babcocki													1,2,21
S. borealis													1
S. brevispinis													1
S. carnatus													7,21
S. caurinus													5,6,8,9,21
S. chlorostictus													2,10,14,21
S. chrysomelas													7,21
S. constellatus													10,14,21
S. crameri													1,7,15,21
S. diploproa													1,6,11,12,21
S. elongatus													1,12,21
S. ensifer													10
S. entomelas													1,2,11,13,21
S. eos													14
S. flavidus													1,2,4,11,21
S. goodei													11,14,21
S. helvomaculatus													1,21
S. hopkinsi													21
S. jordani													2,11,21
S. lentiginosus													10
S. levis													14,21
S. maliger													1,5,15,20,21
S. melanops													1,16, 21
S. melanostomus													21
S. miniatus													11,14,21
S. mystinus													17,18,21
S. nebulosus													19,21
S. nigrocinctus													1
S. ovalis													14,21
S. paucispinis													1,2,4,11,14,21
S. pinniger													1,2,11,21
S. proriger													2,21
S. reedi													1,15
S. rosaceus													10,14,21
S. ruberrimus													1,2,6,12,15,21
S. rubrivinctus													1,10,12,21
S. rufus													21
S. saxicola													1,2,11,21
S. serranoides													20,21
S. simulator													10
S. umbrosus													10
S. wilsoni													1
S. zacentrus													1,2,12,21

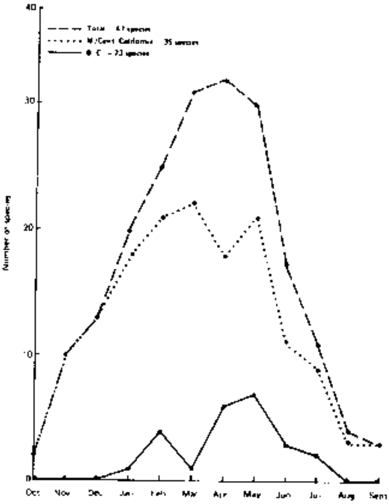


Figure 1.--Number of rockfish species releasing larvae off north / central California and British Columbia by month. Based on Wyllie Echeverria (in press).

Parturition seems to occur earlier in the year in the southern part of the species' range, although data sufficient for such a comparison is available for few species. Annual differences in timing of release of larvae seem to be environmentally determined. In some species studied by Wyllie Echeverria (in press), parturition during the anomalous El Nino year of 1983 was delayed compared to the other years from 1981 to 1985.

Summarizing the data presented by Wyllie Echeverria (in press), there seems to be a slight tendency for rockfishes in the north (British Columbia) to release young later in the year (April-June) than those off north/central California which release young mainly from January to May (Fig. 1). Also, a longer period of release is apparent off north/central California than off British Columbia (Table 2). The median period of release off British Columbia is 1 month, whereas off north/central California it is 3 months. These differences could partially be due to differences in sampling density.

Table 2.--Duration of parturition period of rockfishes by area and number of species (based on Wyllie Echeverria, in press).

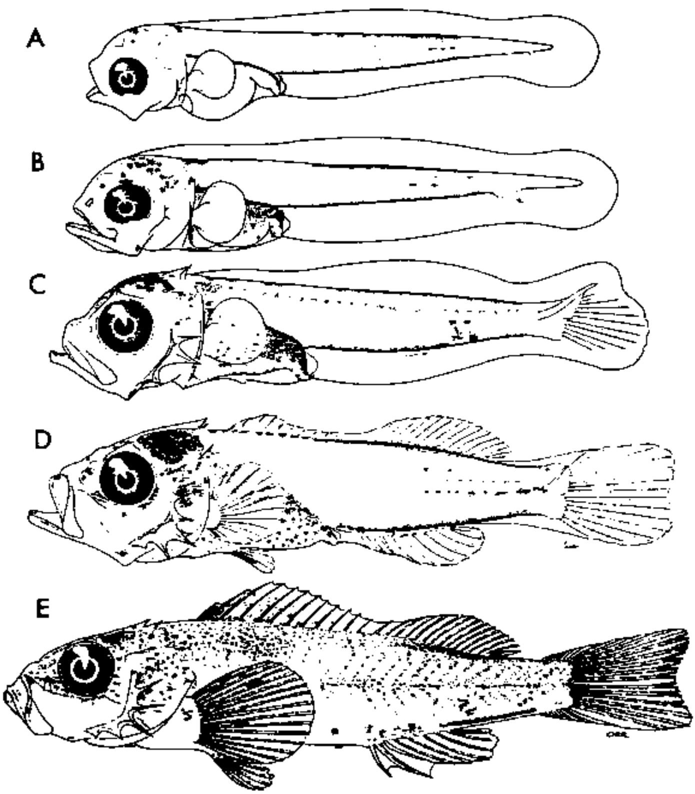
Number of months	Area					
	G of A	BC	Wa	Or	N/C Ca	S Ca
	number of species					
1	3	21	2	6	3	2
2	1	2	1	6	5	5
3	2		2	1	8	1
4				4	2	2
5				2	7	1
6					5	2
>6					5	
total	6	23	5	19	35	13*

*3 species have split season with no release in March or April.

Larval Development

Rockfish larvae are about 3-7 mm SL at birth and have pigmented eyes and a functional mouth (Fig. 2). The trunk and tail is surrounded by an undifferentiated finfold and larval pectoral fins are present. Pigment generally consists of small discrete melanophores in characteristic positions. Although there is considerable interspecific variation in melanophore amount and placement, from nearly absent in S. helvomaculatus to a dark banded pattern on the body of S. aurora, In almost all species some pigment is found on the gut and there is usually a series of postanal ventral midline melanophores. Depending on the species, melanophores may also occur on such places as the jaws, top of head, nape, pectoral fins, dorsal postanal midline, or midlaterally on the caudal peduncle and near the tip of the notochord. Superficial pigment is added in definitive patterns as the juvenile period is approached.

Figure 2.--Development of Sebastes dallí (from Moser and Butler 1981). A. 5.1 mm larva; B. 6.2 mm larva; C. 7.1 mm larva; D. 10.1 mm larva; E. 21.7 mm pelagic juvenile.



With development, the body deepens somewhat and the head enlarges. In postflexion larvae head length is about 28-48% of the body length, preanal length is about 42-66% of the body length, and the maximum body depth is about 21-42% of the body length (Table 3). Head spines start to develop early in the larval period, and soon reach their maximum number and relative size. A full or nearly full complement of spines develops during the larval period, but some are usually lost during the juvenile period to produce the adult pattern that is a specific character. The first head spines to form are the pterotics, several of the preoperculars, and the parietals. Spines continue to be added and to increase in size as the larvae develop. The parietal spines, some of the preopercular spines, and the supraocular ridge become serrate in some species. The parietals and central preoperculars are the longest spines, the parietals reaching 27% of the head length in _S. helvomaculatus_ (Richardson and Laroche 1979). Fin ray formation follows this sequence: caudal, pectorals, pelvics, dorsal, and anal. Fin rays are generally not particularly elongate, although there is variation in the length of the pectoral rays with _S. paucispinis_ pectorals reaching 37% body length in postflexion larvae (Moser et al. 1977). Pelvic rays develop uniquely early in 5-mm larvae of _S. paucispinis_, and reach the same elongate proportion as the pectorals.

Table 3.--Morphometric characters of postflexion larvae of 16 species of northeast Pacific rockfishes, expressed as ranges of percent standard length (SL).

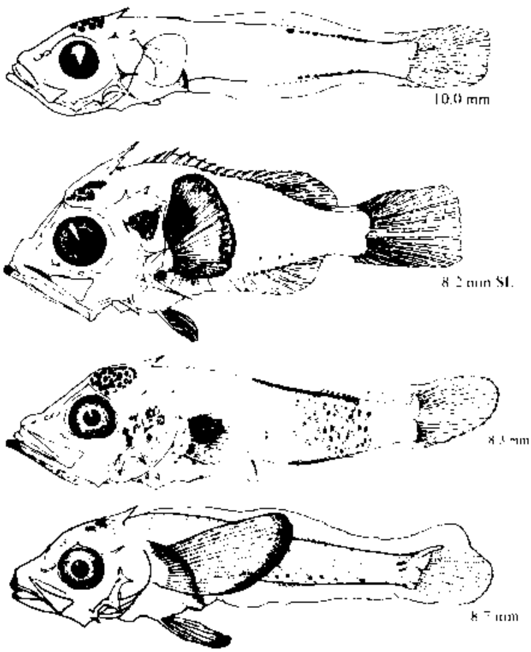
Species	Head length	Body depth	Preanal length	References*
S. auriculatus	30 - 38	22 - 29	47 - 53	20
S. aurora	33 - 40	26 - 34	56 - 66	18
S. caurinus	29 - 36	21 - 29	42 - 54	20
S. crameri	37 - 43	30 - 35	55 - 65	19
S. dalli	28 - 33	22 - 28	48 - 56	16
S. entomelas	34 - 39	25 - 30	55 - 61	9
S. flavidus	35 - 43	25 - 31	54 - 61	8
S. helvomaculatus	40 - 44	33 - 34	59 - 60	19
S. jordani	31 - 36	22 - 26	46 - 54	15
S. levis	34 - 38	33 - 36	57 - 63	15
S. macdonaldi	34 - 41	33 - 36	55 - 64	15
S. melanops	35 - 43	26 - 33	54 - 62	8
S. melanostomus	39 - 44	37 - 42	55 - 63	14
S. paucispinis	36 - 39	28 - 31	51 - 61	15
S. pinniger	38 - 48	34 - 42	52 - 63	19
S. zacentrus	40 - 46	33 - 36	54 - 62	9

*Numbers key to references in Literature Cited.

Larval Identification

Two approaches, or a combination of both, are used to establish the identity of larval fish. The direct approach involves rearing larvae from known parents. The indirect, or series approach, involves finding specimens in field samples that are large enough to have definitive adult (mainly meristic) characters, but small enough to retain some larval characters (such as pigment). A series of similar looking but smaller specimens is accumulated from field samples until the smallest larvae can be recognized. With northeast Pacific rockfishes, yolk-bearing larvae of 50 species have been reared, but only seven species have been reared to caudal fin formation, and only one species has been reared through the larval period. The caudal fin formation larvae are helpful, but not completely definitive, in establishing the identity of field-caught specimens, and the yolk-bearing larvae offer little help at the level to which they have been studied. Thus, with rockfishes larval identification has depended mainly on establishing series. A few species such as S. jordani, S. paucispinis, S. aurora, and S. melanostomus have proven to have very distinctive larvae at all stages of development (Fig. 3) but most, particularly before notochord flexion, seem to look very similar. In several descriptions based on the series approach, larvae smaller than 8-10 mm SL could not be recognized with confidence.

Figure 3.--Flexion stage larvae of (top to bottom) S. jordani (from Moser et al. 1977), S. melanostomus (from Moser and Ahlstrom 1978), S. aurora (from Moser et al. 1985), and S. paucispinis (from Moser et al. 1977).



Descriptions of larvae and pelagic juveniles of various rockfishes are slowly accumulating in the literature, making it reasonable to contemplate using the planktonic stages in field samples for fisheries studies. Among northeast Pacific rockfishes, illustrations have been produced for yolk-sac or preflexion larvae of 50 species, complete larval series of 8 species, and pelagic juveniles of 39 species (Table 4).

Table 4.--Key to sources of illustrations of rockfish larvae from the northeast Pacific Ocean. Numbers key to references in Literature Cited.

Area of occurrence	Larval Stage					Juvenile Stage	
Species	Yolk sac	Preflexion	Flexion	Postflexion	Transformation	Pelagic	Benthic
West Coast of North America							
S. *aleutianus*	4, 24					7	7
S. *alutus*	3, 4, 24					7	7
S. *atrovirens*							
S. *auriculatus*	3, 15, 20	20	20	7		7	7
S. *aurora*		18	18	18	18	18	18
S. *babcocki*	3, 4, 24			7		7	7
S. *borealis*							7
S. *brevispinis*	3, 4, 10					7	
S. *carnatus*	12, 15						
S. *caurinus*	3, 10, 15, 20	20	20	7		7	7
S. *chlorostictus*	12, 15			7	7	7	7
S. *chrysomelas*							
S. *ciliatus*	6						
S. *constellatus*	12, 15, 17		17	17			
S. *crameri*	24			19	19	7, 19	7, 19
S. *dalli*	12, 15, 16	16	16	16		16	
S. *diploproa*	3, 25			7		7	7
S. *elongatus*	12, 15, 25			7		7	7
S. *emphaeus*				7		7	7
S. *ensifer*	12, 15						
S. *entomelas*	6, 17			9	9	7, 9	7, 9
S. *eos*	12, 15						
S. *flavidus*	3			8	8	7, 8	7, 8
S. *gilli*	15						
S. *glaucus*							
S. *goodei*	11, 15					7	
S. *helvomaculatus*	25			19	19	7, 19	7
S. *hopkinsi*	12, 15						
S. *jordani*	10, 11	2, 15		2, 15	2, 15	2, 7, 15	7
S. *lentiginosus*							
S. *levis*	2, 12, 15		2, 15	2, 15	2, 15	2, 15	
S. *macdonaldi*	2, 12, 13, 15	2, 13, 15	13	2, 13, 15	2, 13, 15	2, 13, 15	13
S. *maliger*	3, 25			7	7	7	7
S. *melanops*	10			8	8	8	7, 8
S. *melanosema*							
S. *melanostictus*							
S. *melanostomus*	14, 15			14	14	14	7, 14
S. *miniatus*	15					7	7
S. *mystinus*	4, 22			7		7	7
S. *nebulosus*							7
S. *nigrocinctus*						7	7
S. *notius*							
S. *ovalis*	12, 15, 17	17					
S. *paucispinis*	2, 11, 12, 15	1, 2, 12, 15	1, 2, 12, 15	1, 2, 12, 15	2, 12, 15	7, 12	7
S. *phillipsi*							
S. *pinniger*	15, 21			19	19	7, 19	7, 19
S. *polyspinis*	10					7	
S. *proriger*	25			7		7	7
S. *rastrelliger*						7	7
S. *reedi*	24					7	7
S. *rosaceus*	12, 15					7	7
S. *rosenblatti*	15						
S. *ruberrimus*	3, 5, 6, 25					7	7
S. *rubrivinctus*	17						
S. *rufinanus*							
S. *rufus*	15, 17	17	17				
S. *saxicola*	11, 24			7		7	7
S. *semicinctus*	12, 15						
S. *serranoides*	17	17					
S. *serriceps*	15						
S. *simulator*							
S. *umbrosus*	12, 15						
S. *variegatus*	6, 10			7			7
S. *wilsoni*				7		7	7
S. *zacentrus*	4, 6, 10, 25			9	9	7, 9	7, 9
Gulf of California endemics							
S. *cortezi*	15	15		15		15	
S. *exsul*							
S. *peduncularis*							
S. *sinensis*							
S. *spinorbis*							
S. *varispinis*							

Westrheim (1975) concluded, based on work with preextrusion larvae of 31 species, that "interspecies similarities and intraspecies differences in morphometric and meristic characteristics of preextrusion Sebastes larvae delineated in this study clearly preclude accurate identification, based only on these criteria, of Sebastes larvae caught at sea." He also found that larvae of several species reared to yolk exhaustion changed significantly in pigment pattern from preextrusion larvae. The yolk-sac period in most fishes is characterized by changes in pigment pattern as embryonic pigment migrates and is increased to form the larval pigment pattern. The larval pigment pattern is still not well established in yolk-exhaustion rockfish larvae, so it does not appear possible to anticipate what more advanced plankton-caught larvae of a particular species will look like based on pigment observed in reared preextrusion or yolk-exhaustion larvae.

In spite of these problems there are indications that more detailed studies of reared yolk-sac larvae of rockfishes may be helpful for identifying field-caught specimens. Examining the published illustrations of yolk-sac larvae of 46 species of rockfishes, we established 26 loci where pigment was observed (Fig. 4). We then scored each species based on the presence or absence of pigment at these loci. We found that only two pairs of species could not be separated on the basis of this pigment criterion. There may be problems in comparability of the illustrations because of different illustrators, intraspecific pigment variations, different stages of development, and uncertainty with some adult identifications. However, this excercise indicates that there indeed may be enough interspecific difference in pigment to warrant further study.

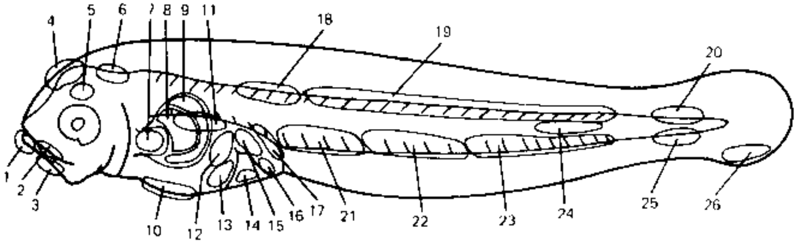
Also, we noted, in the published illustrations and on specimens of several species at our disposal, considerable variation in the appearance of the melanophores that are present on or near the hindgut. The number, size, and location of these seem to be rather consistent within a species, and there is considerable variation among species. Further study will be required to test the utility of this pigment for species separation.

While some changes in pigment occur between hatching and yolk exhaustion, we were struck in the several series we examined by the consistency of pigment in some areas. This indicated that the problem of comparing illustrations and descriptions of preextrusion and yolk-exhaustion larvae may not be severe enough to negate their value completely.

Besides pigment, yolk-bearing larvae have other characters that may be profitable to evaluate. Morphometric characters such as size at stage of development, body depth, and preanal length may prove important. All of the illustrations summarized by Westrheim (1975) were produced by sketching pigment onto a basic template drawing of a rockfish yolk-sac larva. Thus, no morphometric comparisons can be made of these illustrations. Further, the pectoral fins were not included on these illustrations, so the pigment characters of the pectoral fin can not be evaluated for these larvae.

Western Pacific rockfishes, which are larger at extrusion than those in the eastern Pacific, have been reared in large numbers through the juvenile stage for release to enhance natural production (see Moser and

Figure 4.--Pigment loci on yolk-sac larvae of rockfishes. In the body of the table, "1" means pigment present, "2" means pigment absent.



Species	Pigment Loci 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
S. entomelas	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1
S. cillatus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	2	1	2	2	1	2	1
S. crameri	1	1	1	1	1	1	1	1	1	1	1	2	2	1	2	2	2	1	1	1	1	2	2	1	2	1
S. mystinus	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	2	2	1	1	1
S. alutus	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	2	2	1	1	1
S. semicinctus	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	2	1	2	2	2	1	1	1
S. rubberrimus	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	1	1	1	1	2	2	1	2	1
S. hopkinsi	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	1	2	1	1	2	2	1	1	1
S. varigatus	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	2	2	1	1	1	1	2	2	1	2	1
S. brevispinis	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	2	1	1	1	1	2	2	1	2	1
S. reedi	1	1	1	1	1	1	1	1	1	1	2	2	1	1	2	1	2	1	1	1	1	2	2	1	2	1
S. aleutianus	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	2	1	2	2	1	2	2
S. helvomaculatus	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	2	2	1	1	1
S. carnatus	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	2	1	2	1	2	2	2	1	1	1
S. flavidus	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1	1	2	2	1	2	1
S. zacentrus	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	2	2	1	2	2	1	2	2	2	2	2
S. paucispinus	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1
S. rosaceus	1	1	1	1	1	1	1	2	2	2	2	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1
S. cortezi	1	1	1	1	1	1	2	2	1	2	2	1	1	1	2	1	2	1	1	1	1	2	2	1	2	1
S. rufus	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	2	1	2	1	1	1	2	1	1	1
S. saxicola	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	2	1	2	1	2	2	2	1	1	1
S. proriger	1	1	1	1	1	2	1	1	1	1	2	1	1	2	2	2	2	1	1	2	1	2	2	1	2	2
S. elongatus	1	1	1	1	1	2	1	1	1	1	2	1	2	2	1	1	2	1	1	1	2	2	2	1	1	1
S. diploproa	1	1	1	1	1	2	1	1	1	2	2	1	1	1	2	2	2	1	1	1	1	2	2	1	2	1
S. babcocki	1	1	1	1	1	2	1	1	1	2	2	1	2	2	1	2	2	1	2	1	2	2	2	1	2	2
S. macdonaldi	1	1	1	1	1	2	2	2	1	1	2	1	2	2	1	1	2	1	1	1	1	2	2	1	1	1
S. jordani	1	1	1	2	1	1	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1	2	2	1	1	1
S. serriceps	1	1	1	2	1	2	1	1	1	1	2	1	1	2	1	2	2	1	1	1	1	2	2	1	2	1
S. ovalis	1	1	1	2	1	2	2	1	1	1	2	1	1	1	1	2	2	1	2	1	1	2	2	1	1	1
S. goodei	1	1	1	2	1	2	2	2	2	1	2	2	2	1	2	2	2	1	1	1	1	2	2	1	1	1
S. dalli	1	1	1	2	2	2	1	1	1	1	2	1	1	1	1	2	2	1	2	1	2	2	2	2	1	1
S. gilli	1	1	1	2	2	2	2	1	1	1	2	1	1	2	2	2	2	1	2	1	1	2	2	2	2	1
S. constellatus	2	1	1	1	1	1	1	1	2	2	2	1	1	2	1	1	2	1	1	1	1	2	2	1	1	1
S. ensifer	2	1	1	1	1	1	1	1	2	2	2	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1
S. pinniger	2	1	1	1	1	1	1	2	1	2	1	1	1	1	1	1	2	1	2	1	1	2	2	1	2	1
S. rosenblatti	2	1	1	1	1	1	1	2	2	2	2	1	1	2	1	2	2	1	1	1	2	2	2	1	1	1
S. eos	2	1	1	1	1	1	1	2	2	2	2	1	1	2	1	2	2	1	1	1	2	2	2	1	1	1
S. umbrosus	2	1	1	1	1	1	1	2	2	2	2	1	2	2	1	1	2	1	1	1	1	2	2	1	1	1
S. chlorostictus	2	1	1	1	1	1	1	2	2	2	2	1	2	2	1	2	2	1	1	1	2	2	2	1	1	1
S. maliger	2	1	1	1	1	2	1	1	1	2	2	2	1	1	1	1	1	2	2	1	2	2	2	1	1	1
S. miniatus	2	1	1	2	2	2	1	1	1	1	2	2	1	1	1	2	2	1	1	1	1	2	2	1	2	1
S. caurinus	2	1	1	2	2	2	2	1	1	2	2	1	2	2	2	2	2	2	2	1	2	2	2	1	1	1
S. levis	2	1	1	2	2	2	2	2	2	1	2	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1
S. auriculatus	2	1	2	2	2	2	1	1	1	2	2	1	1	1	1	2	2	2	2	1	2	2	2	1	1	1
S. melanostomus	2	2	2	1	2	2	1	2	2	2	2	2	2	1	1	1	2	1	1	1	1	2	1	1	1	1

Butler in press). However, only one eastern Pacific species (S. dalli) has been reared beyond caudal fin formation (Moser and Butler 1981). Among the other most successful eastern Pacific rearings, S. rufus lived to 46 days, S. constellatus to 38 days (Moser and Butler in press), and S. caurinus to 35 days (Stahl-Johnson 1985). Eastern Pacific rockfishes seem amenable to standard techniques developed in other marine fish, but concentrated efforts are needed to obtain healthy full-term larvae from females, and to have proper rearing conditions available for this work. Further progress in rockfish larval identification is largely dependent on rearing developmental series of a wide variety of species.

Larval Distribution

Largely because of identification problems, occurrences of rockfish larvae from ichthyoplankton surveys in the northeast Pacific are usually reported at the generic level (Sebastes spp.). Lisovenko (1964) discussed purported catches of S. alutus larvae made in the Gulf of Alaska in 1963, at a time when the population of S. alutus was much larger than at present. The proportion of S. alutus and other rockfishes in these catches is unknown, since no description of S. alutus is available, and Lisovenko (1964) did not provide diagnostic characters for the larvae he identified as S. alutus.

No field work has been designed specifically to collect rockfish larvae. Occurrences of particular species have been reported in the descriptions of the few species described from field collections (Table 5). These distributional data probably are more indicative of where sampling was conducted, and what samples were examined, than the actual distribution of the larvae. However, the larvae occur to considerable distances offshore (up to 306 km from shore), and several species were not reported nearshore (6 of the 14 species were not found closer to shore than 24 km). Most larval occurrences were in the first 6 months of the year, with the period of occurrence of 7 of the 14 species including April. The season of three species extended to August.

Table 5.--Occurrences of larvae of rockfishes in the northeast Pacific Ocean reported by species.

	Major Features of Occurrences				
Species	Size (mmSL)	Area	Distance from shore (km)	Season	References*
S. aurora		San Francisco-central Baja CA	110-170	Apr-June	18
S. cortezi		Gulf of CA		Mar	15
S. crameri	9-10	Newport, OR	83- 93	Apr-May	19
S. entomelas	10-15	off Oregon	9-306	Apr-May	9
S. flavidus	10-20	off Oregon	24-266	Apr-May	8
S. helvomaculatus	8-20	Newport, OR	83-120	July-Aug	19
S. jordani		San Francisco-San Diego	inshore	Jan-Feb	15
S. levis		California Bight		Jan-June	15
S. macdonaldi		central Baja CA		Mar	15
S. melanops	10-20	off Oregon	5-266	Apr-May	8
S. melanostomus	large	Los Angeles to Baja CA	5-220	Apr-Aug	14
S. paucispinis		CA to Baja CA	nearshore	Jan-Feb	15
S. pinniger	9-20	Newport, OR	83-120	Mar-June	19
S. zacentrus	7-10	off Oregon	46-148	Aug	9

* Numbers key to references in Literature Cited.

Collections of larvae identified as Sebastes spp. (rockfish) from the eastern Bering Sea, the northern Gulf of Alaska, and from off the Washington, Oregon, and California coast have been documented (Table 6). The following summarizes what we know about the distribution of rockfish larvae in these areas. Information based on the occurrences of larvae identified as rockfishes is of limited value, because several species are likely to be included in the collections, and each presumably has a specific pattern of distribution that overlaps those of other species.

Rockfish larvae are vulnerable to collection in plankton nets over a relatively narrow length range. Moser and Butler (in press) found that among over 11,000 rockfish larvae from California Cooperative Oceanic Fisheries Investigations (CalCOFI) plankton collections nearly 50% were less than 5 mm SL, and more than 90% were less than 7 mm SL. In plankton samples taken off Washington, Oregon, and northern California from March through November, little difference in mean size of the larvae was found; they ranged from 4.29 mm in November to 5.61 mm in March-June, and 5.22 mm in August (Northwest and Alaska Fisheries Center (NWAFC) files). Apparently, there is a severe mortality of larvae less than 7 mm, or their avoidance ability increases dramatically at that size. Notochord flexion and the concomitant development of the caudal fin occurs at about 7-8 mm in most species, so increased escapement of larger larvae is probable. Lengths of rockfish larvae have not been reported from other studies, but based on the above nearly all are probably less than 10 mm. Larger larvae and pelagic juveniles of at least some species are collected in neuston nets, where in eight surveys off Washington, Oregon, and northern California the mean length of the 1,112 rockfishes caught was 19.25 mm (NWAFC files).

One consequence of the small size of rockfish larvae in plankton collections is that the larvae are close in time and position to where they were released from the females. Thus, distribution of larvae can probably be used to give a fairly accurate idea of where and when release occurs. Off southern California most rockfish larvae are found in winter; off Washington, Oregon, and northern California most are in spring and summer; and in the Gulf of Alaska and in the Bering Sea most are in summer. Thus, it seems that release of larvae occurs progressively later in the year proceeding from south to north. This agrees with information already cited on seasonality of reproduction based on studies of gonads. The shift in timing of larval release may reflect the seasonal development of oceanographic conditions conducive to producing food suitable for the larvae.

Juvenile Identification

The transition from larval to juvenile stage often is defined to occur when counts of fin rays, gill rakers, and lateral line pores reach adult levels. This stage occurs in many species of rockfish at about 20 mm. Some species do not become juveniles until about 30 mm. Using this definition, many specimens reported as juveniles in the literature and this paper are actually large larvae.

Until the last decade the majority of specimens of juvenile rockfish were identified as Sebastes spp. Several workers have advanced the

Table 6.--Summary of data on *Sebastes* spp. larval collections from major ichthyoplankton programs in the eastern Bering Sea and the northeast Pacific Ocean.

Area	Reference	Years sampled	Months sampled	No. of cruises	collecting stations	*Sebastes* spp. occurrences
Eastern Bering Sea	Waldron [1981]	1955-79	All, mostly Spring--Summer	43	2,435	At 89 stations on 10 cruises, in spring and summer mainly near shelf break, mostly south of 60° N.
	Walline 1981	1979	June-July	1	114	In over 50% of oblique bongo tows throughout sampling area-mainly near shelf break south of St. Matthew's Island.
	Haryu et al. 1985	1970-79	June-August	14	418	592 larvae caught, throughout the southeastern Bering Sea.
Gulf of Alaska	Kendall and Dunn 1985	1972, 1977-79	All except Dec and Jan	11	707	Found late spring through early fall, peak in summer, shift inshore as season progressed.
Washington-Oregon-N. California	NWAFC files*	1980-84	Mar-June, Aug, Oct-Dec	8	873	Nearly equally abundant spring and summer, less abundant in fall, mainly offshore beyond Continental Shelf.
Oregon	Richardson et al. 1980	1972-75	March-April	6	306	Mainly beyond Continental Shelf.
California-Baja California	Ahlstrom et al. 1978**	1950-75	All	157	26,619	Most in winter, decrease abundance in southern part of area, mostly nearshore.

* Kendall, A.W. Jr. pers. comm. Dec. 1986.

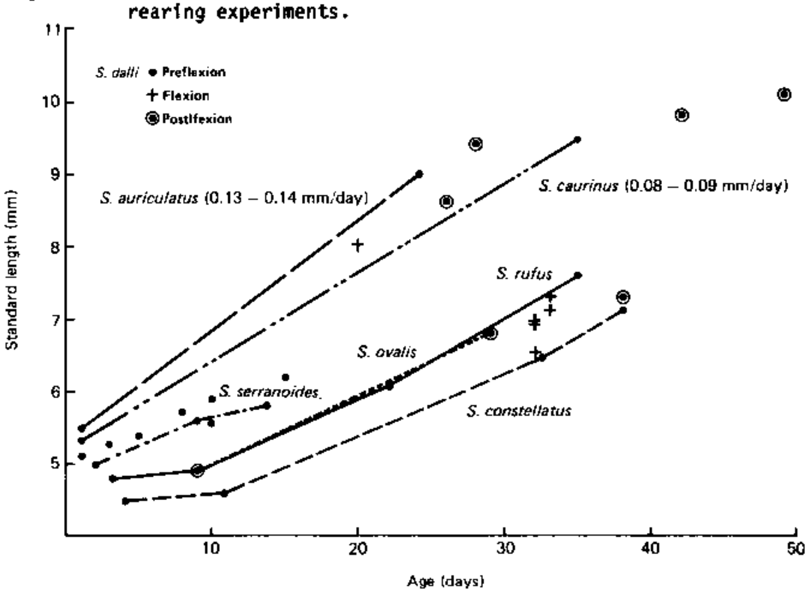
** Loeb et al. 1983 contains more detailed analysis of data from 1975. Other references cited therein contain additional analysis of CalCOFI data.

state of the art so now we can identify most juveniles captured off Washington, Oregon, and California. We were able to identify more than 99% of specimens of juvenile rockfish collected by midwater trawl off central California. Important papers on identification are Laroche and Richardson (1979 and 1980), Moser and Ahlstrom (1978), Moser et al. (1977), Moser and Butler (1981), Moser and Butler (in press), Moser et al. (1985), and Richardson and Laroche (1979). The preceding studies used material collected at sea or from rearing studies. Investigators employing scuba have conducted several nearshore studies of juvenile rockfish off California. Anderson (1983), who includes photographs of 17 species, is the most complete source on identification of juveniles in nearshore areas. The Tiburon Laboratory has developed a key that uses pigmentation patterns and meristics. Laroche is preparing a well-illustrated identification guide. Pelagic juveniles of 37 species will be illustrated in the laboratory guide being prepared by Matarese et al. (in press).

Larval and Juvenile Growth

Little is known about growth of rockfish larvae and juveniles. Under laboratory rearing conditions, change in length with time has been noted for larvae of seven northeast Pacific species. Only S. dalli lived beyond 40 days and a length of 10 mm. There is quite a wide variation shown in growth with some larvae reaching 9 mm in 24 days, while others were only a little over 7 mm after 38 days (Fig. 5). Since larval rearing has not been routinely successful in rockfishes, it is unknown how closely these growth rates reflect those found in the wild, or how much variation is due to different responses to rearing conditions.

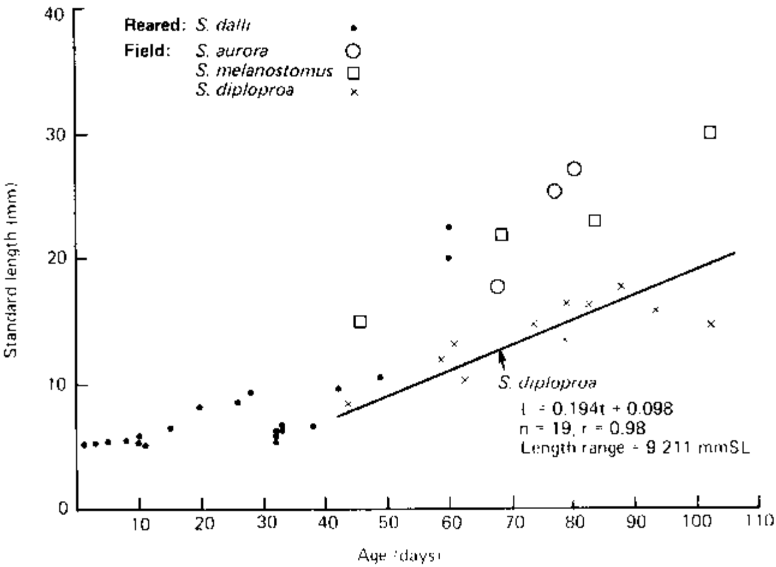
Figure 5.--Growth of northeast Pacific rockfishes based on several rearing experiments.



Boehlert (1982) and Boehlert and Yoklavich (1983) held field-collected pelagic juvenile S. diploproa and benthic juvenile S. melanops under a variety of laboratory conditions of food, temperature, and photoperiod and noted effects on growth using stepwise multiple regression. Growth rate generally increased with increased ration; it was maximal at intermediate temperatures in S. diploproa, but continued to increase at higher temperatures in S. melanops. The temperature of maximal growth increased with fish size in S. diploproa. Growth rates observed in the laboratory under satiation rations were similar to those reported in the field (Boehlert and Yoklavich 1983).

Daily growth increments have been observed on the otoliths of a few juveniles of two species found in albacore stomach contents. The juveniles ranged in length from 15 to 31 mm and in age from 47 to 101 days. The growth rate, determined by otolith aging, of 21 field-collected juvenile (9.0-42.7 mm) S. diploproa (Boehlert 1982) was considerably less than that of the other two species so studied (Fig. 6). When these juvenile data are graphed along with data from reared S. dalli, a coherent picture emerges suggesting slow growth from 5 to 10 mm followed by more rapid growth through 30 mm, although S. diploproa growth seems to continue at a slower rate (Fig. 6). Median fin formation occurs in these species at about 10 mm and possibly the enhanced mobility this provides facilitates the observed increase in growth rate starting at this age.

Figure 6.--Growth or reared Sebastes dalli and size-at-age of field-collected juvenile S. aurora, S. diploproa, and S. melanostomus. Based on Boehlert (1982), Moser and Ahlstrom (1978), Moser and Butler (1981), and Moser et al. (1985).



Life History Patterns of Juveniles

The life histories of rockfish are diverse and complex. It appears that some species may spend nearly their entire lives in a very restricted area. In other cases it appears that life histories may be as complex as those of salmon.

Turner et al. (1969) found 12-mm S. dalli in crevices and caves in proximity to adults, and proposed that the young were released there. The authors did not describe identification procedures. It is possible that identification was incorrect, since larval and juvenile descriptions were not published until 1981 by Moser and Butler. However, there are no records in the literature of pelagic larvae or juveniles of S. dalli.

Work conducted by the Tiburon Laboratory indicates that the life history of S. auriculatus is quite complex. Gravid females occur in San Francisco Bay, but much more often in offshore waters as deep as 80 m. Most S. auriculatus in San Francisco Bay are immature. Pelagic juveniles occur offshore April through June. Benthic juveniles are found in nearshore waters and are abundant in San Francisco Bay. Tagging studies have shown that juveniles spend up to several years within a very restricted home range while in the bay. The fish then gradually move into deeper waters and offshore. Fish tagged as juveniles in the bay have been recaptured several years later more than 80 km away in offshore waters.

While rockfishes possess a range of life history strategies, many species appear to have a juvenile stage which is either pelagic or assoiated with drifting objects such as kelp. However, in addition to S. dalli there are other exceptions to the general rule that rockfishes have an open ocean juvenile stage. Pelagic juveniles of the subgenus Sebastomus (e.g. S. constellatus, S. chlorostictus, and S. rosaceus) as well as S. alutus and S. rufus are noticeably missing or rare in pelagic collections. S. atrovirens, S. carnatus, S. caurinus, and S. chrysomelas recruit to the kelp habitat as large larvae (Anderson 1983). These four species first associate with the kelp canopy and then gradually migrate to the bottom. Thus, their strategy may be a variation of the strategy of species associated with drifting objects as juveniles.

The first review of rockfishes associated with drifting objects is by Mitchell and Hunter (1970). They found juvenile S. diploproa, S. paucispinis, S. rubrivinctus, S. serranoides, and S. serriceps associated with drifting kelp off southern California and Baja California. This stage is particularly important in the life history of S. diploproa (Boehlert 1977). Juvenile S. diploproa were associated with drifting kelp throughout the year. Peak abundance was in May-June. The juveniles appeared to leave the drifting kelp habitat and settle to the bottom between May-June and November-December. Juveniles are about 1 year old when they reach the bottom. Pelagic sampling gear rarely captures juveniles of this abundant species. Boehlert (1977) also presented information on S. paucispinis, S. rubrivinctus, and S. serriceps. S. caurinus and S. nigrocinctus were associated with a drifting glass float found in Queen Charlotte Sound (Hitz 1961). Data presented in the paper suggest that specimens identified as S.

caurinus could have been S. maliger. Since Boehlert's work, the literature contains little about juvenile rockfishes associated with drifting objects. It may prove to be an interesting subject to study north of southern California.

Pelagic sampling gear has captured juveniles of many rockfish species. The two most extensive studies are by Pearcy and Laroche (Table 7) and Adams, Lenarz, Moreland, and Wyllie Echeverria (Table 8). Pearcy and Laroche captured 15 species of juvenile rockfish off Oregon and Washington using purse seines. S. entomelas, S. flavidus, S. melanops, and S. mystinus were abundant in their collections. Peak catches for 12 of the 15 species were in June. Catches of S. diploproa, S. nigrocinctus, and S. proriger were low and peaked in September. They do not report juvenile S. alutus, which is a common species in their area. Adams et al. captured 22 species of juvenile rockfish off central California with a midwater trawl. They captured significant numbers of S. auriculatus, S. entomelas, S. flavidus, S. goodei, S.

Table 7.--Catches of juvenile rockfishes by purse seine sets off Oregon and Washington, 1979-1984. Mesh size was 3.2 cm (stretched). (N = number of juveniles, Y = number of years of occurrence) (Personal communication W. Pearcy and W. Laroche, Oregon State University, Newport, Oregon).

Month	May		June		July		August		September	
Number of Sets	124		335		119		67		152	
Species	N	Y	N	Y	N	Y	N	Y	N	Y
S. crameri	0	0	2	2	0	0	0	0	0	0
S. diploproa	0	0	1	1	0	0	0	0	13	1
S. emphaeus	1	1	0	0	0	0	0	0	0	0
S. entomelas	9	1	283	5	0	0	0	0	0	0
S. flavidus	0	0	589	6	0	0	0	0	0	0
S. goodei	1	1	1	1	0	0	0	0	0	0
S. jordani	9	2	73	6	1	1	0	0	0	0
S. maliger	0	0	1	1	0	0	0	0	0	0
S. melanops	1	1	369	5	0	0	0	0	0	0
S. mystinus	1	1	432	3	2	1	0	0	0	0
S. nigrocinctus	0	0	0	0	0	0	0	0	18	2
S. paucispinis	0	0	14	3	0	0	0	0	0	0
S. pinniger	1	1	8	1	0	0	0	0	0	0
S. proriger	0	0	0	0	0	0	0	0	14	1
S. saxicola	0	0	17	1	0	0	0	0	0	0

Table 8.--Catches of juvenile rockfishes by midwater trawls off of central California. A 25-m head rope length trawl with a 1.3-cm stretched mesh cod end was used. Towing depth varied from 10 to 100 m. April was sampled 1985 and 1986. Late May and June were sampled 1983-1986. (N = number of juveniles, O = number of occurrences, Y = number of years of occurrence). (Personal communication P. Adams, W. Lenarz, S. Moreland and T. Wyllie Echeverria, Southwest Fisheries Fisheries Center, Tiburon, California).

Month	April			Late May-June		
Number of Tows		48			357	
Species	N	O	Y	N	O	Y
S. auriculatus	205	12	1	532	83	2
S. caurinus [1/]	0	0	0	9	6	1
S. crameri	0	0	0	15	10	2
S. diploproa	1	1	1	3	3	1
S. entomelas	0	0	0	15,335	99	4
S. flavidus	0	0	0	893	86	4
S. goodei	460	21	2	603	57	3
S. hopkinsi	1	1	1	1,374	41	3
S. jordani	134	17	2	84,828	180	4
S. levis	0	0	0	1	1	1
S. melanops	0	0	0	99	23	3
S. miniatus	1	1	1	0	0	0
S. mystinus	11	7	2	2,817	47	3
S. nigrocinctus	0	0	0	3	2	1
S. paucispinis	7	6	2	1,029	81	3
S. pinniger	16	8	2	242	65	3
S. rastrelliger	0	0	0	1	1	1
S. saxicola	16	10	2	65	22	3
S. semicinctus	0	0	0	10	7	2
S. serranoides	0	0	0	12	5	2
S. serriceps	0	0	0	3	3	1
S. wilsoni	4	3	1	20	8	3

[1/] Specimens classified as _S. caurinus_ could also be _S. carnatus_, _S. chrysomelas_, or _S. maliger_.

hopkinsi, S. jordani, S. mystinus, S. paucispinis, and S. pinniger. Peak catches of most species occurred in late May-June, but S. auriculatus, S. goodei, and S. saxicola are more abundant in April. They did not capture S. rufus, which is abundant in their area. In addition to the list of species collected as juveniles in Tables 7 and 8, S. helvomaculatus is reported by Richardson and Laroche (1979), S. macdonaldi by Moser (1972), S. melanostomus by Moser and Ahlstrom (1978), and S. zacentrus by Laroche and Richardson (1980).

Studies have found newly transformed benthic juveniles of many species both in nearshore and offshore waters. Anderson (1983) provides data on the timing of settlement in the nearshore habitat off central California for 15 species (Table 9). His data indicate that S. entomelas, S. goodei, S. jordani, and S. paucispinis only occasionally used this study area. The remaining 11 species regularly used the area. He also obtained a few specimens of S. semicinctus and S. rosaceus. Feder et al. (1974) report juvenile S. atrovirens, S. miniatus, S. mystinus, S. paucispinis, and S. rastrelliger in kelp beds off southern California. Hobson (pers. commun. Sept. 1986, Southwest Fisheries Center, Tiburon, California) has found significant numbers of S. caurinus, S. flavidus, S. melanops, and S. mystinus in kelp beds of northern California. Turner et al. (1969) found juvenile S. auriculatus, S. caurinus, S. dalli, and S. serranoides associated with man-made reefs in nearshore waters off southern California.

Sherwood and Mearns (1981) captured large numbers of juvenile S. saxicola, S. diploproa, and S. jordani using a bottom trawl off southern California. Moser and Ahlstrom (1978) captured benthic juvenile S. melanostomus off southern California. Chen (1971) captured juvenile S. rosenblatti and S. umbrosus on the bottom off southern California.

Table 9.--Number of juvenile rockfish in nearshore waters (<25 m) off central California (Anderson 1983).

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S. atrovirens	0	0	0	0	0	56	50	88	47	90	35
S. carnatus - S. chrysomelas	0	0	0	2	82	312	91	43	20	7	0
S. caurinus	0	0	46	95	207	115	7	67	27	4	0
S. entomelas	0	0	0	0	11	17	5	0	0	0	0
S. flavidus	0	0	9	14	141	119	76	32	22	51	1
S. goodei	0	0	0	0	6	0	1	1	0	0	0
S. jordani	0	0	0	0	5	6	2	0	0	0	0
S. melanops	0	0	3	6	113	68	44	20	9	20	0
S. miniatus	18	6	4	5	7	6	28	19	16	3	0
S. mystinus	0	0	13	101	326	129	77	40	36	9	0
S. paucispinis	2	2	6	18	59	14	10	8	8	4	0
S. pinniger	0	0	15	154	130	111	17	35	38	22	0
S. saxicola	0	0	14	3	59	117	214	100	109	0	0
S. serranoides	0	0	4	19	144	82	42	49	11	10	7

Love and Lee (1974) report on S. rubrivinctus caught by bottom trawl off Santa Barbara. Lenarz et al. (pers. commun. Sept. 1986, Southwest Fisheries Center, Tiburon, California) captured juveniles of 11 species with a bottom trawl off central California (Table 10). S. saxicola was particularly abundant. Apparently, midwater trawl gear does not adequately sample S. crameri, S. saxicola, and S. semicinctus in April-June off central California (Tables 8 and 10). Benthic juveniles of S. flavidus and S. melanops were collected off Oregon by Laroche and Richardson (1979); S. entomelas and S. zacentrus by Laroche and Richardson (1980); and S. crameri, S. helvomaculatus, and S. pinniger by Richardson and Laroche (1979). Carlson and Haight (1976) report that juvenile S. alutus begin settling in Alaskan fiords when they reach around 40-55 mm in length. S. alutus do not appear to settle until their second year of life.

May, June, and July are important months for juvenile rockfishes off Washington, Oregon, and California, when the young fish are important forage items for other fish (Merkel 1957) and for birds (Wiens and Scott 1975) and are at peak abundance in midwater catches (Table 7 and 8). Also, most major species transform to benthic juveniles during this time. Anderson (1983) reports peak catches of small benthic juvenile S. flavidus, S. melanops, S. mystinus, S. paucispinis, and S. serranoides during June (Table 9). These catches suggest that June is the peak month of transfer from the pelagic to nearshore stage for these species. Hobson (pers. commun. Sept. 1986, Southwest Fisheries Center, Tiburon, California) has found during the past 10 years that S.

Table 10.--Catches of juvenile rockfishes by 30 bottom trawls off of central California during June 1984. A 12-m head rope length trawl with a 1.3-cm stretched mesh cod end was used. Bottom depths were less than 200 m. (N = number of juveniles, O = number of occurrences) (Personal communication W. Lenarz, S. Moreland and T. Wyllie Echeverria, Southwest Fisheries Center, Tiburon, California).

Species	N	O
S. auriculatus	1	1
S. constellatus	1	1
S. crameri	17	4
S. flavidus	5	3
S. hopkinsi	12	2
S. jordani	3	2
S. paucispinis	1	1
S. pinniger	10	3
S. saxicola	201	12
S. semicinctus	7	3
S. wilsoni	2	2

flavidus, S. melanops, and S. mystinus first begin recruiting to nearshore habitats of northern California between late May and late June. Hobson's observations also provide some insight into other aspects of the juvenile stage. He has observed that the size of newly recruited juveniles is noticeably larger in some years than others. This suggests that size is not the only factor that triggers transition from one juvenile stage to another. He also has observed that during some years recruitment of these species to the nearshore habitat is concentrated into a period of less than a month, whereas during other years it is spread over several months.

Juvenile Field Studies

A study of rockfish recruitment was initiated in 1983 by the Tiburon Laboratory. Reports are available on progress through 1985 (Lenarz and Moreland 1985, Hobson et al. 1986). This section reviews these reports and adds some information obtained in 1986.

The study has three major objectives. The first is to develop methods for predicting year-class strength for economically important species of rockfish. Most species of rockfish are not recruited to fisheries until the age of 4-10 years. The study attempts to estimate year-class strength in the first year of life, and thus give fishermen and managers a basis for planning. The goal is to detect severalfold changes in year-class strength. Such precision has been shown to be appropriate for management purposes (e.g. Lenarz 1971). The study area originally included the coastal and offshore waters between Point Sur and Cape Mendocino, California. Beginning in 1986, the offshore work was limited to the area between Monterey and Bodega Bay. The study emphasizes seven species of rockfish that are important in the area: S. entomelas, S. flavidus, S. goodei, S. jordani, S. melanops, S. mystinus, and S. paucispinis.

The second objective is to gain a better understanding of factors that affect strength of recruitment, the most important factor underlying the success of fisheries. Although there must be a relationship between recruitment strength and the quantity and quality of eggs or larvae produced by adults, that relationship is obscured by poorly understood environmental factors. The Tiburon Laboratory is studying annual changes in reproductive physiology of adults, the relationship between oceanic conditions and recruitment success, and the fine-scale timing of reproductive success (daily ages of juveniles).

The third objective is to develop a better understanding of the ecological niches of juveniles of important species. About 60 species of rockfish occur in California and about 20 species are fairly abundant in the study area. These closely related species are similar in appearance in the juvenile stage. The ecology of some juvenile rockfishes is fairly well known during the nearshore stage, but little is known about the ecology of any species during the pelagic juvenile stage. We are studying feeding habits and environmental factors that affect distribution of pelagic juveniles, as well as adding to the existing knowledge of the nearshore stage.

Samples in the offshore area are collected with a midwater trawl that is slightly modified from the gear used by Mais (1974). The net has a 25-m headrope and 1.3-cm mesh liner in the codend. Tows 15 minutes in duration are made during darkness. Daylight tows were tried and discontinued because of low catches. Standard warp is 30 m for tows in depths less than 92 m and 90 m in deeper waters. Replicate tows are made at some stations for comparative purposes. Most of the work is conducted from late May through the end of June, but some work is done in April.

Analysis of replicate midwater tows made at some stations indicated that only one tow per station was necessary. The 90-m warp catches were larger than the 30-m warp catches, but the differences were not statistically significant. The power of the test was low because of small sample sizes. However, catches at these two depths were significantly correlated. We are collecting more data on depth distribution.

Midwater catches were lowest in 1983 and highest in 1985. Catches were similar in 1984 and 1986. An analysis of variance produced significant differences between 1984 catches and 1985 catches of S. flavidus, S. goodei, S. jordani, and S. paucispinis, but not S. entomelas.

Previous to 1986 one set of midwater trawl stations was occupied between Point Sur and Cape Mendocino. The 1985 season demonstrated to us that settlement can occur in late May-early June. We thus narrowed the area to Point Sur to Bodega Bay and will attempt to sample all stations three times during the season. The highest replicate will be used for the index of abundance.

Results from Oncorhynchus tshawytscha and nearshore Ophiodon elongatus stomach content analyses are promising. We believe that we may be able to eventually replace midwater trawl surveys with stomach content analyses to produce routine indices of abundance for important species of juvenile rockfish.

Scuba surveys are made in shallow nearshore waters of northern California's Sonoma and Mendicino coasts. The laboratory conducts scuba surveys to about 35 m every 2 to 3 weeks as weather permits. Two or three divers equipped with marking slates note numbers of juveniles during timed segments along random courses in representative habitats.

The nearshore studies are providing data on two species that do not appear to be sampled well by the midwater trawl survey, S. melanops and S. mystinus. In addition, the nearshore results are similar to the offshore results for S. flavidus. Statistically significant differences were found in 1983, 1984, and 1985 for S. flavidus, S. melanops, and S. mystinus.

The Laboratory began work on adult reproductive physiology and daily age determinations during the past year. It is premature to present a progress report on these two studies.

The Tiburon Laboratory plans to follow the basic field plan for the next several years. We intend to make statistical comparisons of the midwater trawl and stomach content data in a few years. We will drop the midwater trawl work if the stomach data appear to be adequate. We are attempting to obtain another vessel during May-June to examine some questions we have on the relationship between oceanic conditions and the distribution of the juvenile rockfishes.

It will be a number of years before we know how well the indices of abundance perform as predictors of year-class strength. However, there is already some evidence that indices will produce satisfactory results for S. paucispinis.

Implications for Management

Adult biomass estimation

The lack of pelagic eggs in rockfishes has several consequences for fisheries scientists. The use of surveys of pelagic eggs to estimate spawning biomass of fish populations is becoming a standard practice in several fisheries. This technique has been considered for several decades, and now is reaching a level of sophistication that makes it the method of choice for population estimates in several cases. Since rockfishes do not have pelagic eggs, this method cannot be considered for these fish. The pelagic larvae of fish can be used to estimate spawning biomass, but as the time between spawning and collecting increases, the effects of mortality and dispersion make the estimates less and less reliable. This method could be considered for rockfishes known to have very distinctive early larvae (e.g. S. jordani and S. paucispinis); however, early larvae of most rockfishes all look quite similar and it may not be possible to identify them routinely in plankton samples. To use eggs or larvae for a population estimate, details of reproductive parameters such as fecundity and distribution of spawning must be known rather precisely. This information is being accumulated for rockfishes, but is not yet generally available for these applications.

Larval identification

Since there are so many rockfishes in the northeast Pacific, and since larvae of few of them appear to be readily identifiable, their use in recruitment studies seems doubtful in the near future. Larval series (illustrations of a yolk-sac and/or preflexion larva, a flexion larva, and a postflexion larva) are only known for 9 of the 71 species. Among these are four species with distinctive larvae (S. aurora, S. jordani, S. melanostomus, and S. paucispinis), but the others may be confused with species that have not yet been described. Descriptions of larvae of other species are accumulating slowly, and rearing of northeast Pacific rockfish larvae has proven difficult so far. A further complication to the larval identification problem is that most of the rockfish larvae collected in plankton surveys are too small (<8 mm) to have distinctive meristic characters. The critical stages for establishing series, those between flexion larvae and pelagic juveniles (which have distinctive pigment patterns and adult meristic characters), are very rare indeed in plankton collections. It should be noted in particular that development of S. alutus, the most common and heavily fished rockfish in the Gulf of Alaska and Bering Sea, remains undescribed between the yolk-sac larvae and pelagic juvenile stages. While the use of rockfish larvae in fisheries studies is not impossible, scientists and managers should realize their limitations and gear expectations accordingly.

Longevity

The adult life histories of rockfishes are as varied as the early life histories. In this section we will discuss longevity, its effect on management, and implications for using estimates of year-class strength made during the year of birth.

S. jordani is a very abundant unexploited species (Lenarz 1980). It is relatively short-lived (rarely older than 10 years). This species could probably sustain relatively high rates of exploitation. Consequently, a fishery would probably be supported by one to several year classes. Early estimation of year-class strength is important for such a fishery because a year class only produces significant contributions to landings for a few years at most.

S. entomelas is a moderately-lived species (fish older than 30 years uncommon). The species supports moderate levels of exploitation (Hightower and Lenarz 1986). Strong year classes occur every few years. Uncertainty in the strength of incoming year classes has resulted in errors of about 25% in estimation of acceptable biological catch for the Pacific Fisheries Management Council.

S. alutus is a very long-lived species (oldest specimens approach 100 years). This species can only support low rates of exploitation (Ito et al. 1986), and stocks are depleted in most if not all areas. Fish do not fully recruit to the fishery until age 10 or more, and strong year classes occur only about once per decade. The ability to detect such year classes at an early age would provide managers and industry with a valuable planning tool.

While there is a wide range of longevity in rockfish, it appears that in general, management and industry would benefit from estimates of year-class strength at an early age. We hope to make such estimates from pelagic and nearshore surveys of juvenile rockfish densities.

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Addendum

MacGregor, J. S.
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This paper was published too late to be included in our review. It contains an analysis of occurrences of rockfish larvae collected in the CalCOFI program, and discusses distributions of S. jordani, S. paucispinis, S. macdonaldi, and S. levis specifically.